Comparison between system design optimization strategies for more electric aircraft networks

Djamel Hadbi, Nicolas Retière, Frédéric Wurtz, Xavier Roboam, Bruno Sareni

COMPARISON BETWEEN SYSTEM DESIGN OPTIMIZATION STRATEGIES FOR MORE ELECTRIC AIRCRAFT NETWORKS

Djamel Hadbi*, **, Nicolas Retière*, Frederic Wurtz*, Xavier Roboam**, Bruno Sareni**

*Univ. Grenoble Alpes, G2Elab, F-38000 Grenoble, France, CNRS, G2Elab, F-38000 Grenoble, France
firstname.lastname@g2elab.grenoble-inp.fr

**Université de Toulouse, LAPLACE, UMR CNRS-INPT-UPS, 2 rue Camichel, 31071 Toulouse, France
firstname.lastname@laplace.univ-tlse.fr

Abstract. Nowadays, embedded aircraft system contains electrical devices which must cooperate in safe and light weight network. For designing such systems, different local strategies have been developed but no global optimization has been performed so far. In this paper, we present and compare three strategies applied to the sizing of a whole network of more electric aircraft: a simplified case study with only two components is considered to illustrate methodological issues. The quality of the solution found from each method is compared, with regards to the "cost of the collaborative approach" and the volume of data generation. This comparison should provide system designers an evaluation of the applicability of these methods according to the nature of the design problem.

Keywords: system design, integrated design, multilevel optimization, embedded electrical system.

INTRODUCTION

Modern engineering products are becoming increasingly complex, particularly in industries such as railway, aerospace and automotive [1], [2]. Conventionally, expertise and classical analysis methods, especially those based on simulations are used, aided by optimization methods in some part of the process. Each sub-system is designed separately by his manufacturer using his own model and process: this method is called "mechanistic approach". Another approach called "simultaneous design" may be developed to integrate all the components of a system into a single optimization. This extreme approach requires full cooperation for best results [2]. Another diametrically opposite approach enables to design a system with a minimal collaboration. This method called Extended Pareto Fronts was developed for the design of a railway application [3]. Industrial design imposes other constraints, integration of a large scale multidisciplinary system, privacy issues and decision level are fundamental criteria to elaborate feasible and efficient system design method [2].

I. DESIGN MODEL OF A SIMPLIFIED STUDIED CASE

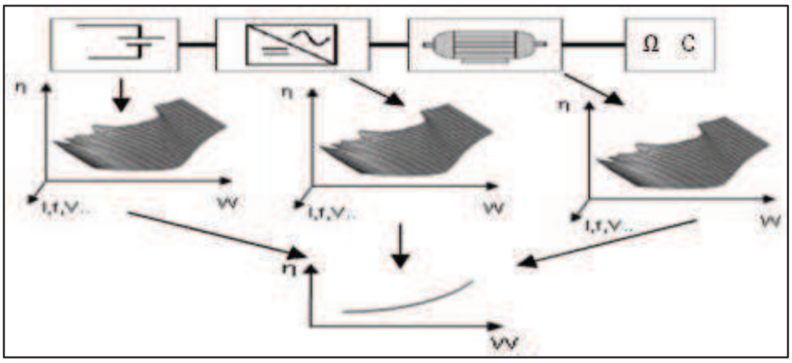

Figure 1. Design of an actuator by Extended Pareto Front Method

Extended Pareto Front Method (EPFM) is based on the decomposition of a system in several devices, each of them being previously optimized separately, only coupled by global variables (i. e. I, f, V in the figure 1). It intends to limit the communication of data between the suppliers. Only Extended Pareto Optimal Fronts (space solution) are provided by suppliers to the system designer. First, a necessary condition has to be checked: in a suitable decomposition, the system objective function has to be calculated by means of the objective functions of sub-problems. If so, a classification of all problem variables allows identifying global variables that describe couplings on the system. In the above example, there are N=3 couplings variables, i.e. current (I), frequency (f) and voltage (V) of the bus, completed by O=2 objective functions for weight (W) and device efficiency (η). So a N+O-dimension solution space is built for each component of the system. Gathering the Extended Pareto Fronts of all amenities, the system manufacturer shall be able to make tradeoffs within the sets of solutions in order to obtain the best solution at the system level. Of course, not any combination of equipment is possible; the manufacturer must be careful of the consistency of coupling variables that ensure the compatibility of the chosen amenities.

II. DESIGN OF A SIMPLIFIED EMBEDDED ELECTRIC NETWORK

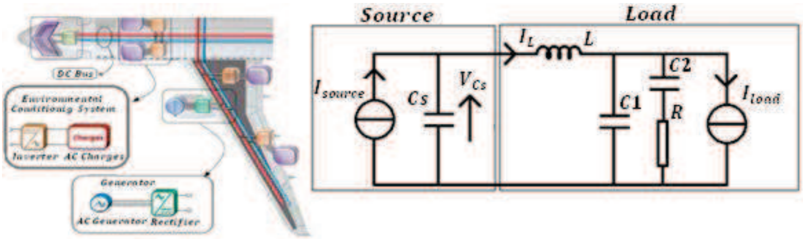

Figure 2. An example of a simplified embedded electric network

Embedded electric networks contain a high number of sources and loads connected to several buses: the issue is then to analyze applicability of optimization methods to this class of complex system. In our study, related to the development of strategies for system design, we initially relied on a “simplified” network, which is voluntary limited to a single load in order to establish and compare optimization methods. It consists of a single generating channel, connected with a unique non-linear load. This channel includes a generator, a rectifier and an output filter. The load comprises an actuator, an inverter and an input filter. We investigate the design of this channel (especially the filtering device sizing) using the three approaches previously presented: the optimization goal is to minimize the whole network weight in compliance with quality standards; (current and voltage harmonics are limited to a maximum threshold in a frequency band). Let us note that this case study consists of a single objective optimization for which the previous method (EPFM) of course remains applicable.

III. QUALITATIVE COMPARISON OF RESULTS

As shown in the figure 2 (left part), the values of the objective function obtained by two collaborative methods, the simultaneous design approach and Extended Pareto Front Method are better than the value of the objective function obtained with a conventional method (“mechanistic approach”) based on expertise and classical analysis methods.

Collaboration level and calculation cost are conflicting characteristics as illustrated of the right part of figure 2: higher is the collaboration level, lower the necessary computational cost to reach the perfect solution. The mapping of the space solution of a sub-problem grows exponentially with the number of coupling variables (if there are P values of M input global variable, P^M optimizations are done). High level of collaboration means that subsystem manufacturers need to share and communicate their models for the design process. So it’s easy for the system integrator to improve the whole system generating a small amount of data. On the other side, a low level of collaboration means that each subsystem designer keeps its design secret, so that he must provide more data to aircraft manufacturer to enable him finding the optimal combination of subsystems.

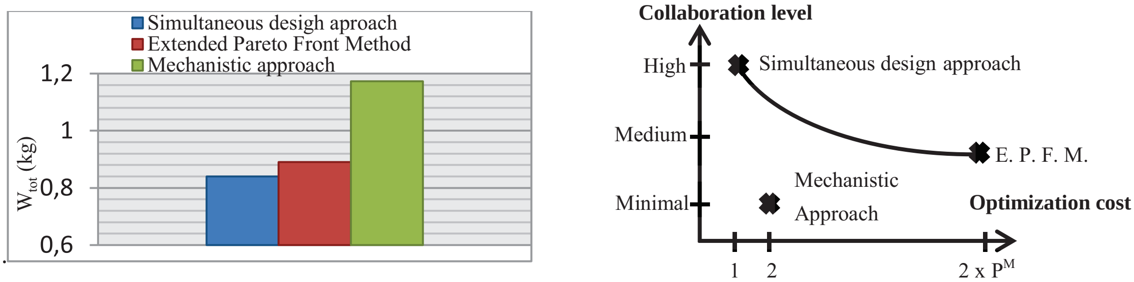

Figure 3. Comparison of optimization approaches in terms of objective function and costs (collaboration vs computation cost)

CONCLUSION

Through our work, we managed to check out conditions are necessary to elaborate a design strategy for complex system: collaboration and data generation. Thanks to this, we have proposed a multilevel collaborative design strategy while limiting the data exchanged by the designer of system components which is a requirement for industrial systems such as embedded networks.

REFERENCES

[1] F. Moussouni-Messad, “Multi-level and multi-objective design optimization tools for handling complex systems”, these (PHD) de l’Ecole Centrale de Lille 2009.

[2] X. Roboam & al, “Integrated design by optimization of electrical energy systems’’, edited by ISTE Wiley, 2012, ISBN 978-1-84821-389-0.

[3] H. Nguyen-Huu , N. Retière, F. Wutz, “A new approach for building the global Pareto border of an electromagnetic system by using the Pareto borders of each sub-component of the system”, IEEE-CEFC 2008 (International Conference on Electromagnetic Field Computation), ID: OC1-4 in proceeding of the conference.